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AN EVALUATION OF THE GEOLOGICAL HISTORY AND HYDROCARBON POTENTIAL OF THE LATE MIOCENE - ? PLIO/PLEISTOCENE SEDIMENTS OF THE GOUDRON FIELD - TRINIDAD

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ABSTRACT

The Goudron Field lies in the Southern Basin onshore Trinidad, on the south-eastern flank of the Rock Dome/Lizard Springs anticlinal trend. A sedimentary sequence of Upper Cretaceous to late Tertiary sediments has been penetrated by the 174 wells drilled in the area. However, to date, only the late Miocene and ? Plio/Pleistocene contain productive hydrocarbon reservoirs.

Two major episodes of late Miocene/ ? Plio-Pleistocene sedimentation have been identified. The older comprised a period of sediment gravity flows into a bathyal environment in the Late Miocene/ ? Early Pliocene which resulted in the deposition of interbedded shales, silts, sands and conglomerates of the Moruga Formation. The younger comprised a period of fluvio-continental deposition in the ? Plio-Pleistocene and resulted in the sands and minor silty clays of the Mayaro Formation.

Deposition of the Moruga Formation was followed by a major tectonic event, resulting in the formation of the Pilote Syncline and the Pre-Mayaro Unconformity. Minor Episodes of ? late Pliocene/Pleistocene faulting are also evident.

The field was discovered in 1927 and has produced 4.6 mm barrels of oil to date and may still contain significant reserves to be exploited.

INTRODUCTION

The Goudron Field was discovered in the 1920's, aggressively drilled throughout the 1940's and 1950's, and has been virtually abandoned since that time. Over the period of drilling activity, 174 wells penetrated mainly the shallow, productive Upper Miocene -? Plio/Pleistocene sediments, from which 4.6 mm barrels of oil have been produced. A few wells were also drilled beyond this productive section.

All available data from these wells including electric logs, one dipmeter log, full-hole and sidewall cores, palaeontological reports, and production data were incorporated in the study. Other available data comprised field outcrop and augur samples, Kugler's surface geology map of Trinidad (1959), and geophysical data. The latter consisted of a gravity survey run in 1950, which covered only a small portion of the field and was virtually useless, and an east - west trending seismic (1966) line which provided valuable additional information.

The Goudron Field is situated in the Guayaguayare Sub-basin which lies south of the Rock Dome/Lizard Springs Anticline in the eastern part of the Southern Basin (Fig.1). It lies approximately 30 miles due east of TRINTOPEC's active land operation. The closest TRINTOPEC field under development is Moruga East which lies approximately 5 miles to the west and within which drilling activity has been minimal. Activity in the Goudron Field has been suspended since the 1960's, and much of the existing infrastructure including roads, tanks, pumping station and buildings may require extensive refurbishing and upgrading if an aggressive development/exploration programme is initiated. In the more remote areas, the terrain is rugged and heavily forested, and therefore initial exploration costs may be relatively high.

Abblewhite and Higgins (1965) gave a brief outline of the geology of the field, but since that time no further publications have been made.

STRATIGRAPHY AND SEDIMENTATION

The hydrocarbon-bearing sediments consist of the sands of the older Moruga and younger Mayaro Formations (Figs. 2,3,4). While it is difficult to place these formations in time throughout the late Miocene to Pleistocene, certain pertinent facts have been noted, as follows:

- The basal part of the Moruga Formation is dated late Miocene (post Globorotalia acostaensis).
- The cyclicity of the sedimentation within the two formations could be indicative of eustatic changes

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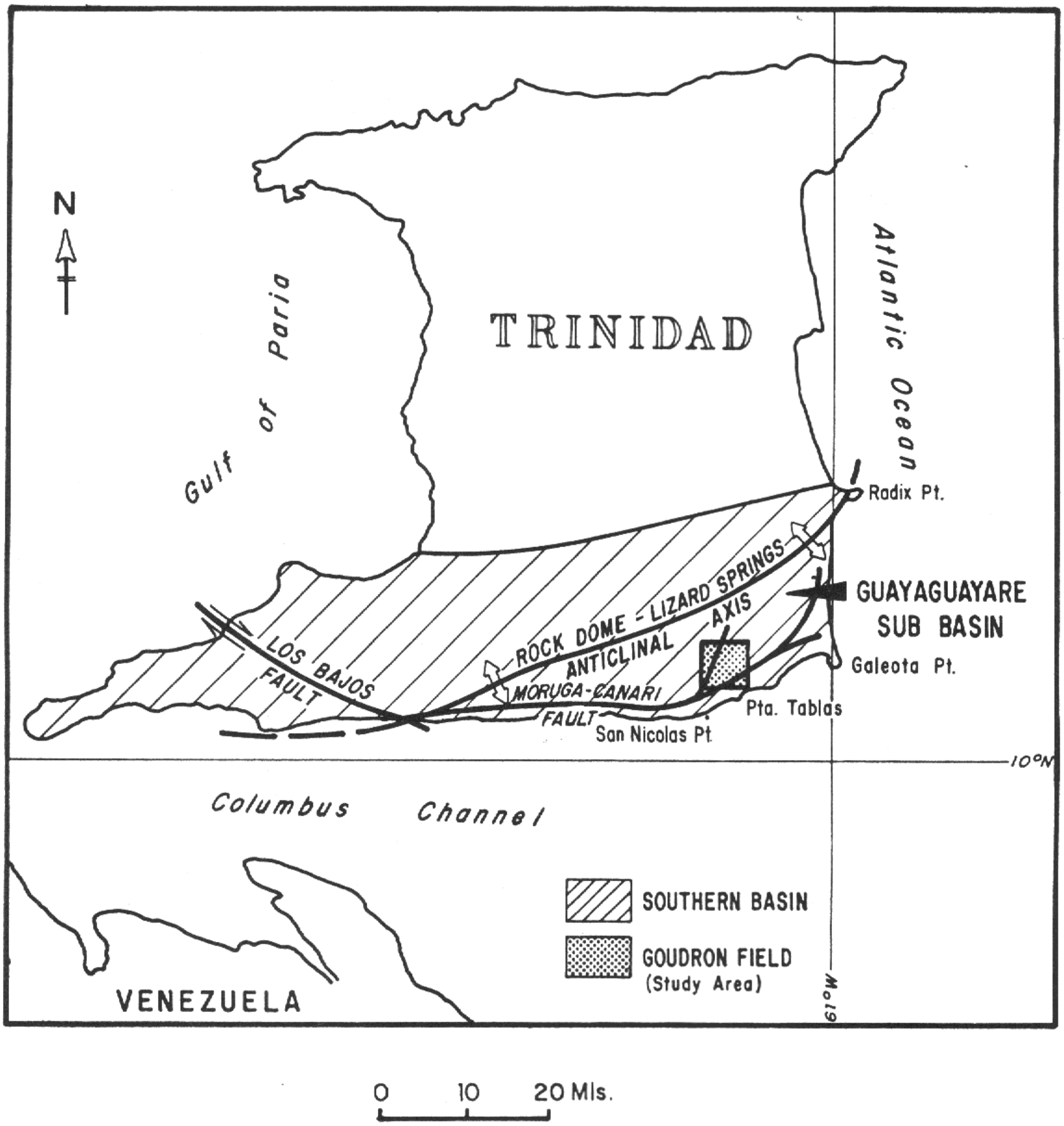

Fig. 1 – Location Map

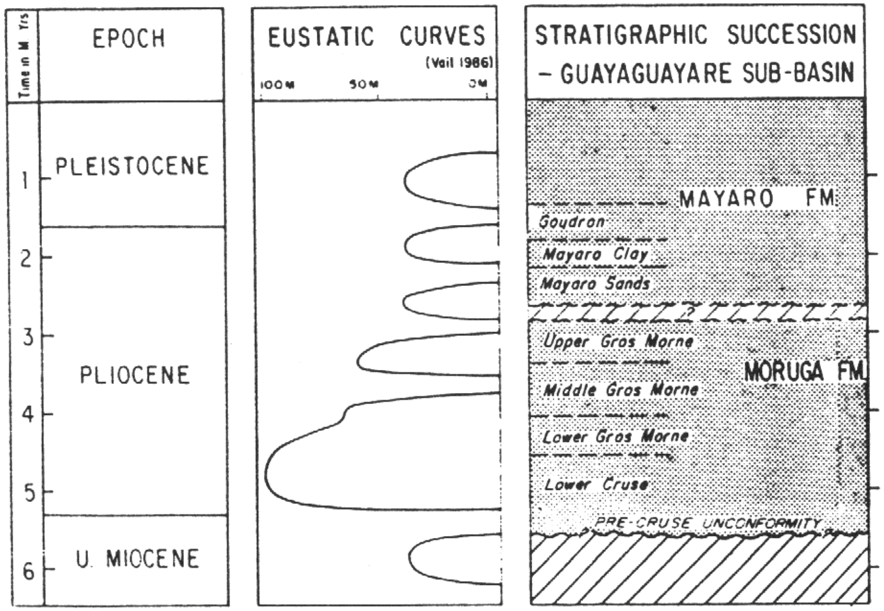

Fig. 2 - Stratigraphic Chart - Guayaguayare Sub Basin with possible relationship to sea-level changes

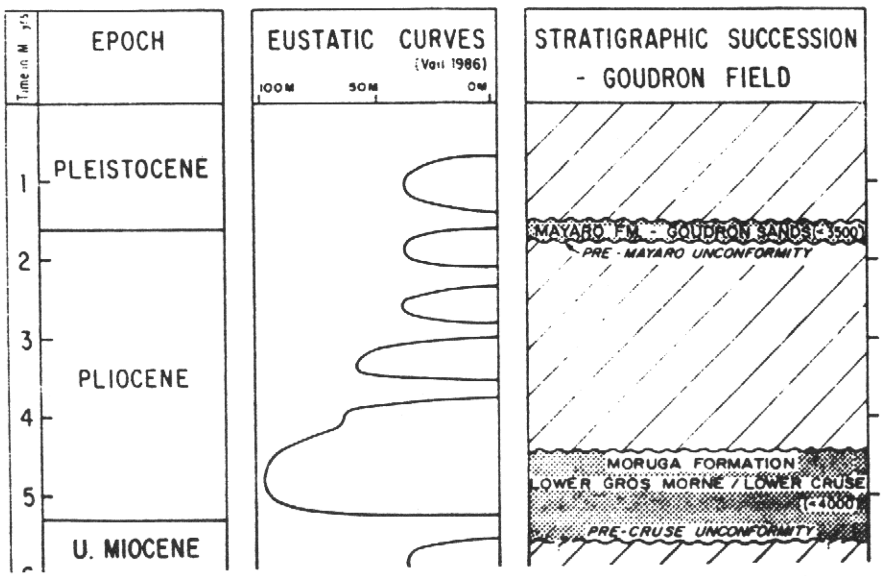

Fig. 3 - Stratigraphic Chart - Goudron Field with possible relationship to sea-level changes

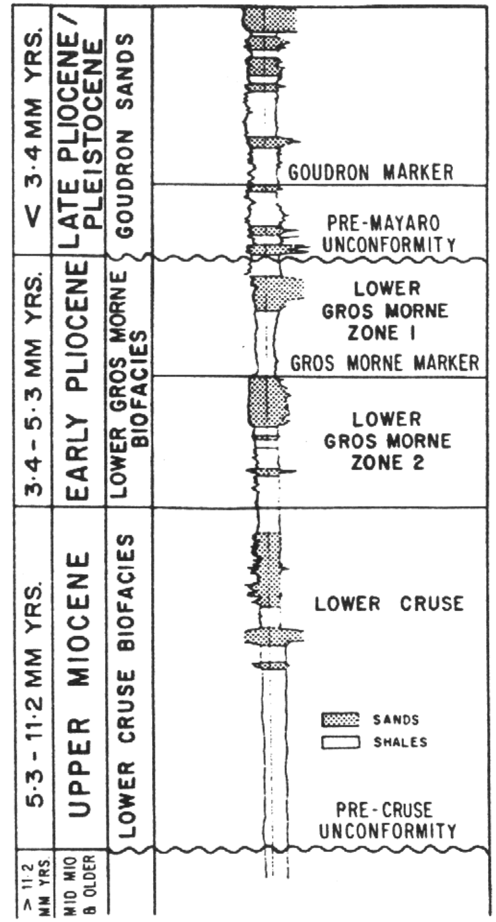

Fig. 4 - Composite Type Log Goudron Field

throughout this time, and there may be correlations between these cycles of deposition and documented worldwide eustatic changes throughout the Miocene - Pleistocene (Figs. 2, 3).

Moruga Formation

The Moruga Formation is late Miocene-?Pleistocene in age, and is underlain unconformably by the Eocene Lizard Springs Formation (Cushman and Jarvis 1928), and the Upper Miocene Lengua (Renz 1942) and Karamat (Suter 1951) Formations, from which it is separated by the Pre-Cruse Unconformity (Figs. 3, 4, 4a). The particular formation which directly underlies the Moruga Formation changes from place to place within the field depending on the formation exposed below the Pre-Cruse Unconformity. The Mayaro Formation unconformably overlies the Moruga Formation.

The Moruga Formation attains a maximum thickness of 4000 feet and is represented within the field by its basal members, the Lower Cruse and Lower Gros Morne Biofacies (Figs. 2, 4). Well-defined lithological markers have been used to subdivide the Moruga Formation into, from oldest to youngest, Lower Cruse, Lower Gros Morne Zone 2 and Lower Gros Morne Zone 1, (Figs. 4, 6, 7, 8). It consists of dark grey to black, immature, slightly calcareous clays, which contain pyrite, mica, glauconite, pebbles and boulders (including chert, calcareous nodules, pepper and salt sandstone, limestone, argilline, marl, clay, mudstone), and sand/silty-sand laminae and beds.

The clays yield a heterogenous fauna consistent with the heterogenous lithologic texture, and these indicate considerable reworking of older Miocene, Oligocene, Eocene, Palaeocene and Cretaceous formations into late Miocene-? Plio/Pleistocene sediments. The fauna are arenaceous and comprise predominantly outer-shelf valvulinids, and these indicate deposition in an outer shelf/upper slope environment.

The sands in these zones range in thickness from a fraction of an inch when they occur as laminae to ±300 ft in thickness. They are fine to medium-coarse grained, silty, and contain pebbles and boulders of siltstone, vuggy limestone and buff-coloured marl. These sands are interpreted as turbidites deposited in an outer shelf/upper slope environment.

Through palaeogeographic reconstructions, the topography of the surface on which the sediments of the Moruga Formation were deposited ie. Pre-Cruse Unconformity surface, has been defined, and it is apparent that this surface controlled deposition of the overlying turbidite sands of the Late Miocene-? Plio/ Pleistocene (Fig. 5). During that period, the depositional surface deepened westward and was characterized by the occurrence of east-west trending ridges and intervening "lows" within the field area. Dips on the flanks were 14°±. Sands subsequently deposited in this basin became confined to the "lows" between the up-folds, and because of westerly deepening, all the sediments downlap the unconformity surface eastward, so that younger and younger sediments are in contact with the unconformity surface in that direction (Figs. 6,7,8).

Mayaro Formation

The exact age of this formation is unknown at the present time but it could be Pliocene or as young as the Pleistocene (Figs. 3,4). On-going geological studies may lead to a more exact determination of its age in the future. It is underlain unconformably by the Moruga Formation from which it is separated by the Pre-Mayaro Unconformity, which it onlaps to the west, northwest and southeast (Fig. 11). It outcrops at surface, and is found preserved only in the northern part of the field.

Palaeogeographic reconstruction of the topography of the surface on which the sands of the Mayaro Formation were deposited could be done only in the northern part of the field and indicates close parallels between the features of this surface and the features of the structures created by ? Plio/Pleistocene tectonism which preceded its deposition (Figs. 9, 10). The receiving basin appears to have been traversed by a number of east-west trending, parallel ridges and intervening lows which approximately correspond to the main structural elements of the Moruga structure including the Pilote Syncline, Fault AA', and the northern flank of a southerly upthrust block (Figs. 9, 10).

These facts, coupled with the fact that the present-day structures within the Mayaro Formation closely parallel the palaeotopography in "Mayaro" time, suggest that no tectonism has occurred since the ? Plio/Pleistocene event. (Figs. 9, 10, 12).

The Mayaro Formation is represented by its uppermost member, the Goudron Sandstone, which consists of laminated, cross-laminated and bedded, rippled sandstones, whose sparse fauna, including brackish water miliammina, and lithological character indicate deposition in a nearshore environment (Figs. 3, 4). The sands are fine-very fine grained, fair-well sorted, non-calcareous, silty in part, contain lignite and mica, and are occasionally interbedded with thin shales and silty sand (Figs. 4, 13). The cumulative thickness of these sands exceeds 3000 ft in the east central part of the field (Fig. 11).

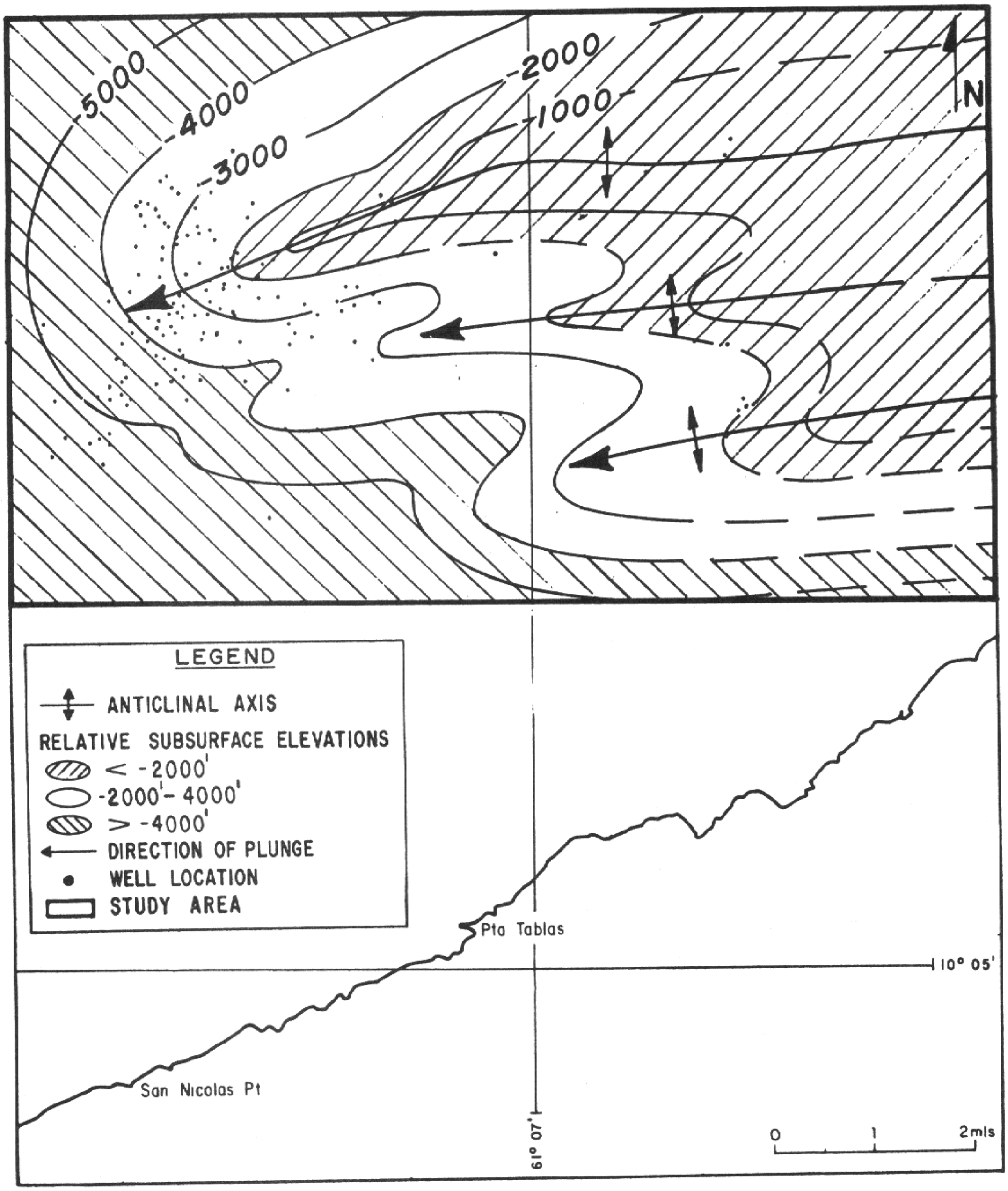

Fig. 5 - Palaeotopography - Late Miocene
(Basin Configuration prior to deposition of Moruga Fm.)

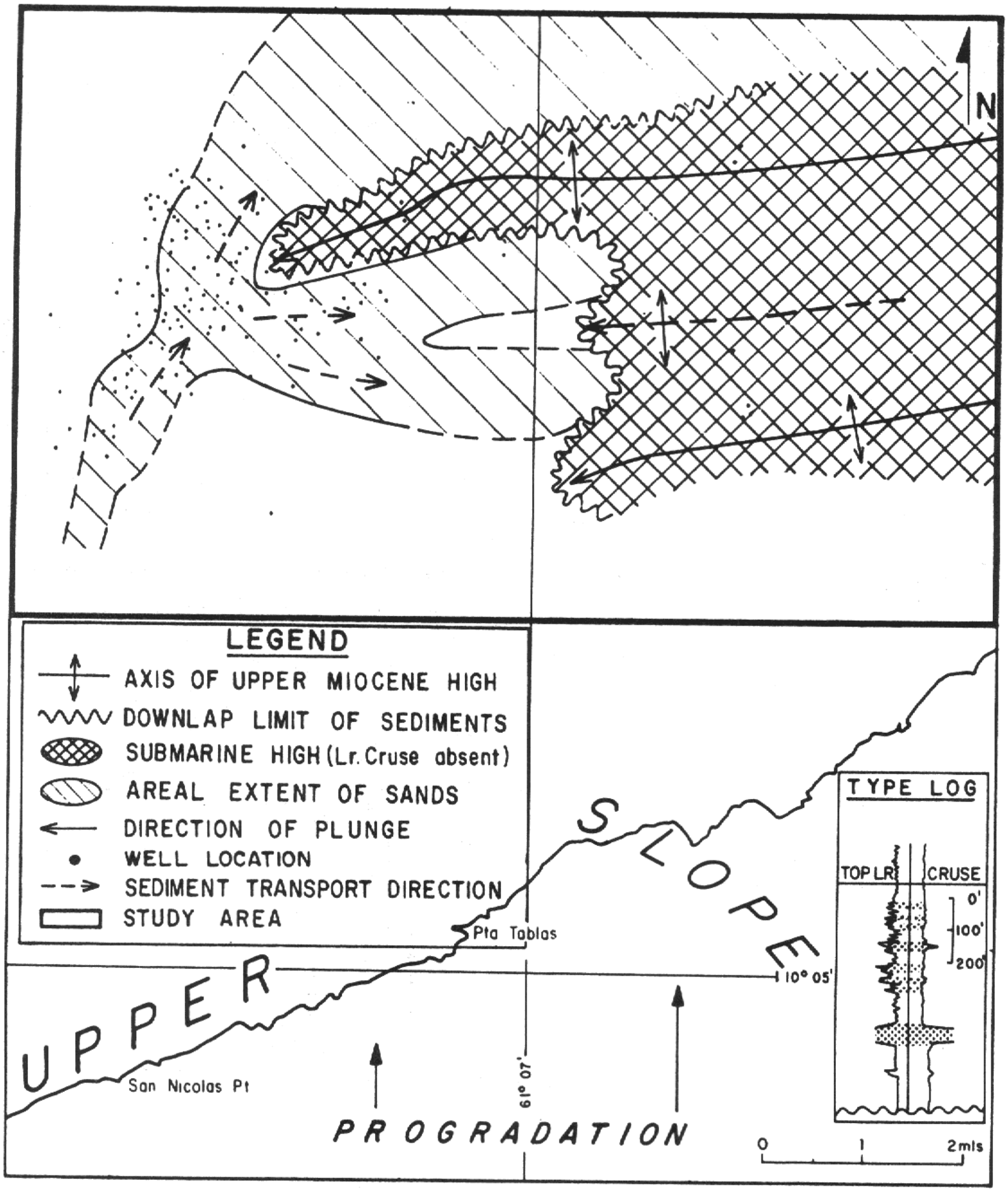

Fig. 6 - Sand Distribution - Lower Cruse

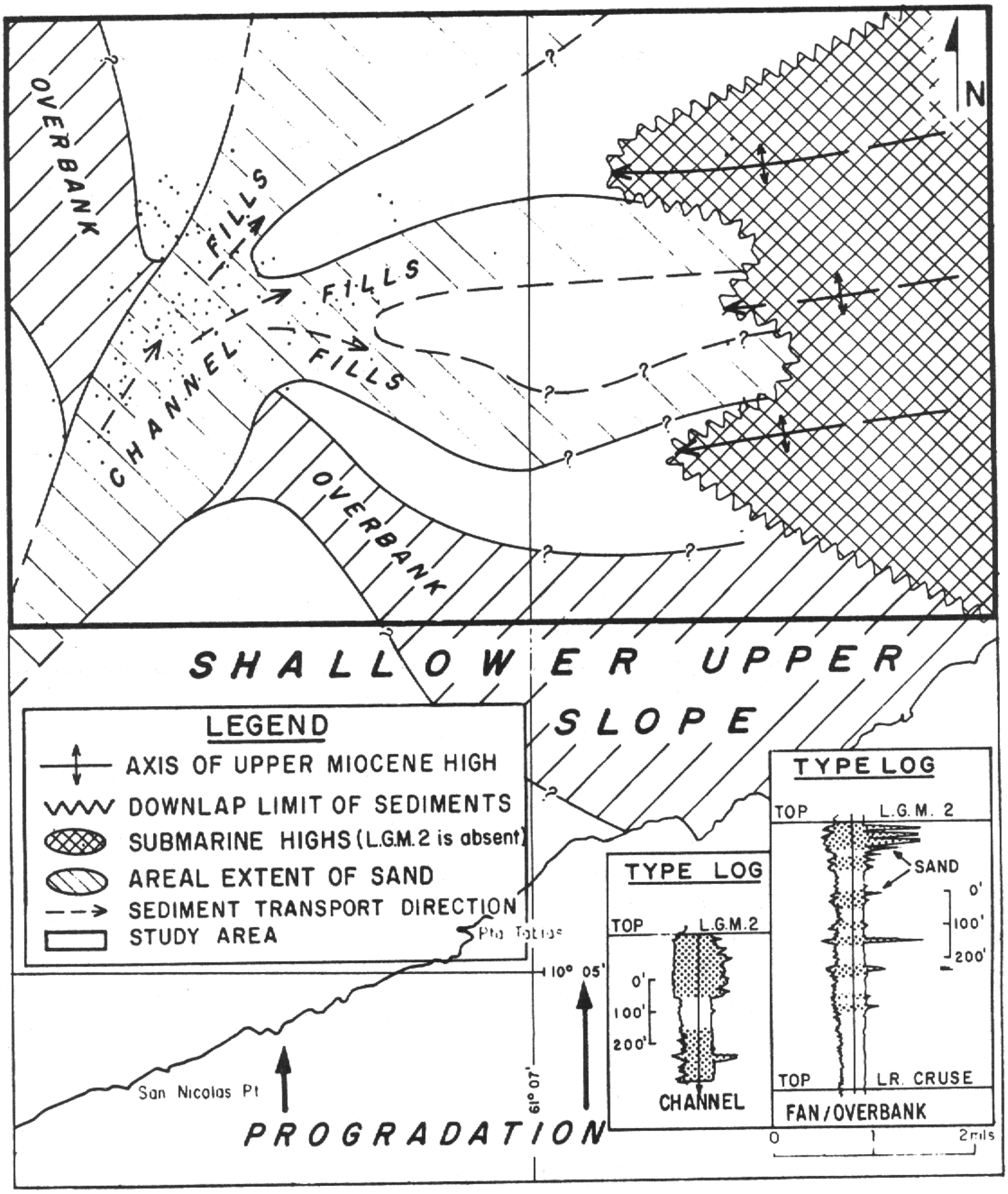

Fig. 7 - Sand Distribution - Lower Gros Morne Zone 2

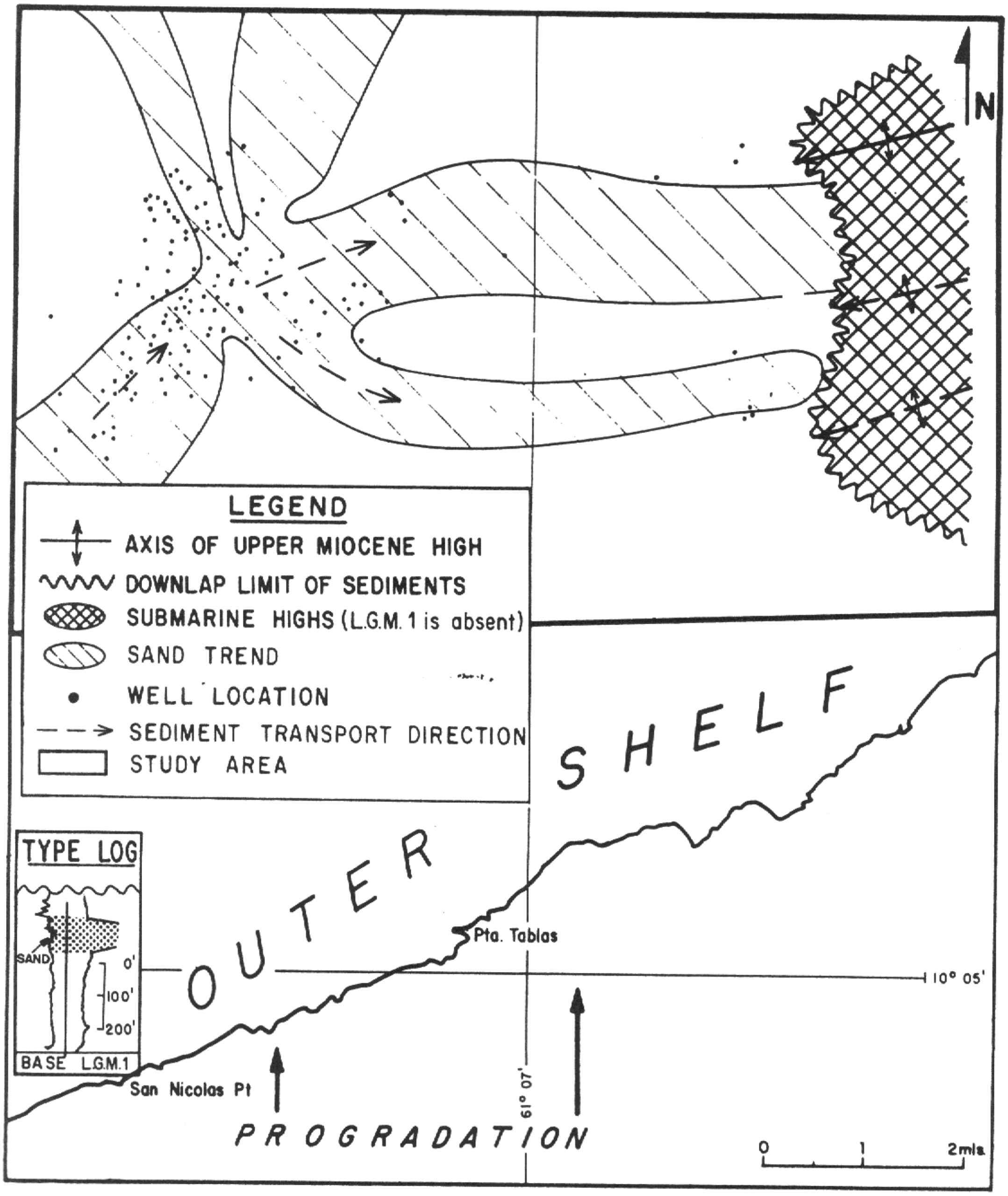

Fig. 8 - Sand Distribution - Lower Gros Morne Zone 1
(Truncation by Pre-Mayaro Unconformity at Top of Section)

STRUCTURE

Well-defined lithological markers were established by well to well correlation of electric logs, and these markers were used to establish the structural history of the late Miocene to?Plio/Pleistocene sediments (Fig. 4a). Two major tectonic events were responsible for the present-day structures within this field. These include a mid-Miocene event and a ? Plio/Pleistocene event (Fig. 3). The former coupled with erosion created the Pre-Cruse Unconformity whose topography influenced deposition of sediments of the Moruga Formation. The latter structured sediments of the Moruga Formation and created the pre-Mayaro Unconformity, whose topography influenced deposition of the sediments of the Mayaro Formation.

Pre-Cruse Unconformity (Figs. 3, 4, 5)

This is a major unconformity resulting from a well-defined mid-Miocene tectonic event, which resulted in the creation of a series of parallel, east-west trending highs running through the field (Fig. 5). Wells which penetrated the unconformity have encountered sediments of mid-Miocene, Eocene, and Palaeocene ages directly below the unconformity surface, depending on their locations. Following the erosion which accompanied the mid-Miocene tectonism, sediments of the Moruga Formation were deposited on the Pre-Cruse Unconformity from as early as the late Miocene.

Structure - Moruga Formation

This structure is the result of a ? Plio/Pleistocene tectonic event that followed deposition of sediments of the Moruga Formation. The exact timing of this event is unknown at this time due to lack of available data.

The Pilote Syncline was one of the major structural features which resulted from this tectonism (Fig. 9). It is a NE-SW trending syncline, whose axis runs through the northern part of the field and plunges to the east. It is asymmetrical, being more steeply dipping on its northwestern flank than on its southeastern flank. As a result, dips vary from 53° E in the west, to 25° straddling the synclinal axis, and 18° N on the southeastern flank of the syncline.

Several major north-south and east northeast -west southwest trending faults dissect the syncline. One fault, AA', is a north-south trending, right lateral, wrench fault and offsets the synclinal axis by .8 km. While this is the present day offset, this displacement is estimated to have been approximately .5 km prior to deposition of sediments of the overlying Mayaro Formation, since lateral displacement along fault AA' is evident, though to a lesser degree in the Mayaro Formation. The other faults are northeast - southwest trending thrust or normal faults, with vertical displacement ranging between 200 ft to 1000 ft.

Pre-Mayaro Unconformity

This is an unconformity which lies between the Moruga and the Mayaro Formations, and is the result of a tectonic event which followed deposition of sediments of the Moruga Formation (Figs. 3, 4, 10). The exact timing of this event is unknown, but could be as early as the early Pliocene or as late as the Pleistocene. The unconformity is only represented in the northern part of the field.

Structure - Mayaro Formation

This "structure" is the result of drape of sands of the Mayaro Formation over the Pre-Mayaro Unconformity, and ?Plio/Pleistocene right-lateral wrench faulting. As a result, the sands of the Mayaro Formation are "folded" into two, sub-parallel, east-west trending synclines whose axes are offset 0.3 km by north-south trending wrench fault, AA'. Both synclines plunge to the east due east of wrench fault AA', and to the west due west of this fault. Dips on the synclinal flanks average 30° east of fault AA' and 25° west of it.

HYDROCARBON POTENTIAL

The Goudron Field has been highly productive in the small area developed in the west-central part of the field. Because of its early abandonment, barely 20% of its productive potential has been realized since its discovery in 1927, from late Miocene to ? Plio/Pleistocene sediments, and though it is presently non-productive, considerable quantities of hydrocarbons, in the order of ±20 mmbo remain to be produced. Oil production in the Moruga Formation is derived from combination structural and stratigraphic traps within structures associated with right-lateral wrenching, and within shoe-string turbidite channel sands interbedded with shales (Figs. 6,7, 8, 13). Some oil is also found in similarly structured overbank fan sands.

While significant production has been obtained from sands of the Mayaro Formation, no well-defined trap is evident, since there is no significant seal. The oil in this formation seems to have a strong affinity to the sands in contact with the pre-Mayaro Unconformity surface. It appears that oil may be currently migrating along the unconformity surface, and that some of it becomes temporarily reservoired in the lowest sands, before being completely lost at surface. (Fig. 13).

It can be inferred that the Moruga Canari Wrench fault system taps the established Cretaceous source rocks at depth beneath the

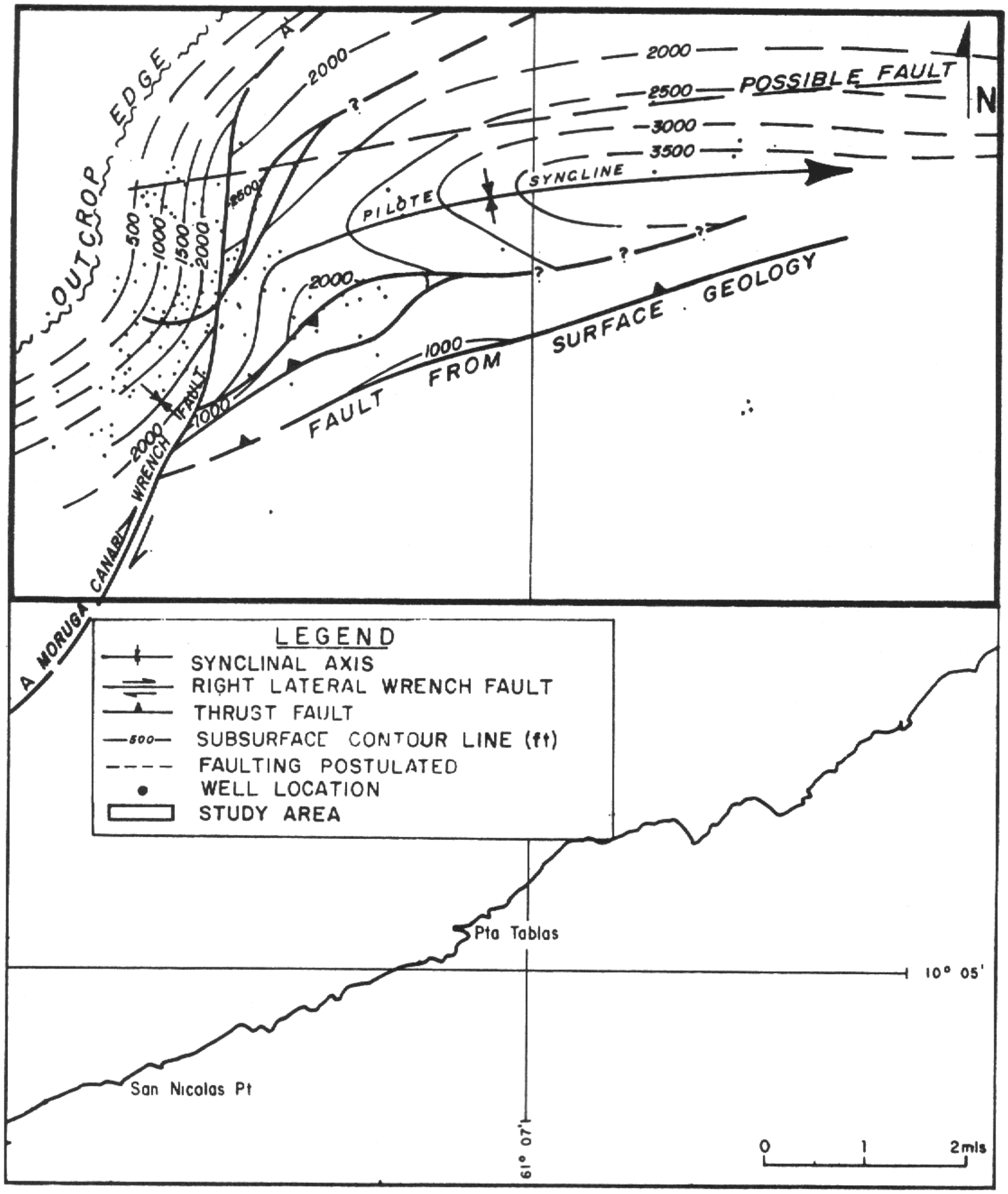

Fig. 9 - Structure Contour Map - Gros Morne Marker

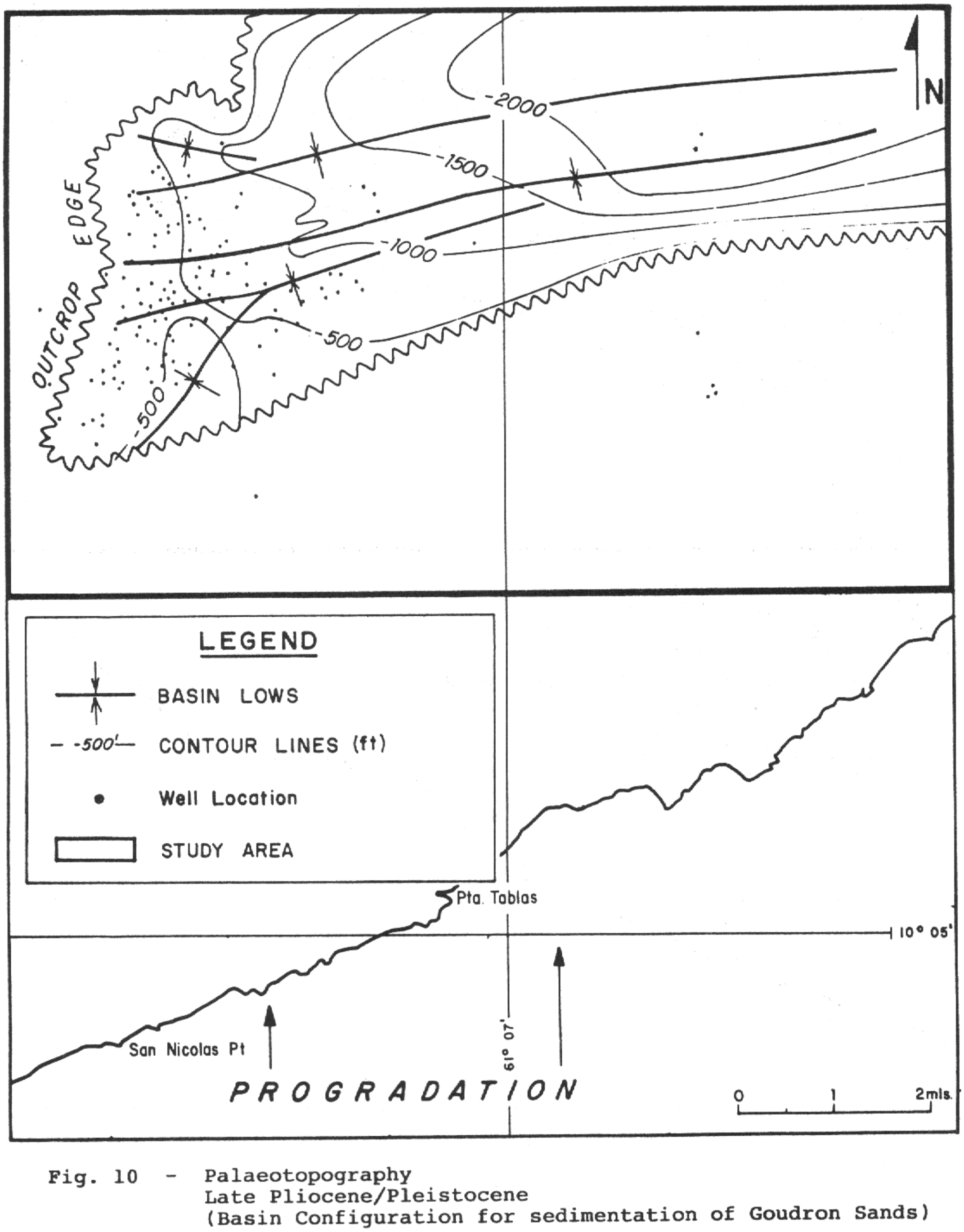

Fig. 10 - Palaeotopography
Late Pliocene/Pleistocene
(Basin Configuration for sedimentation of Goudron Sands)

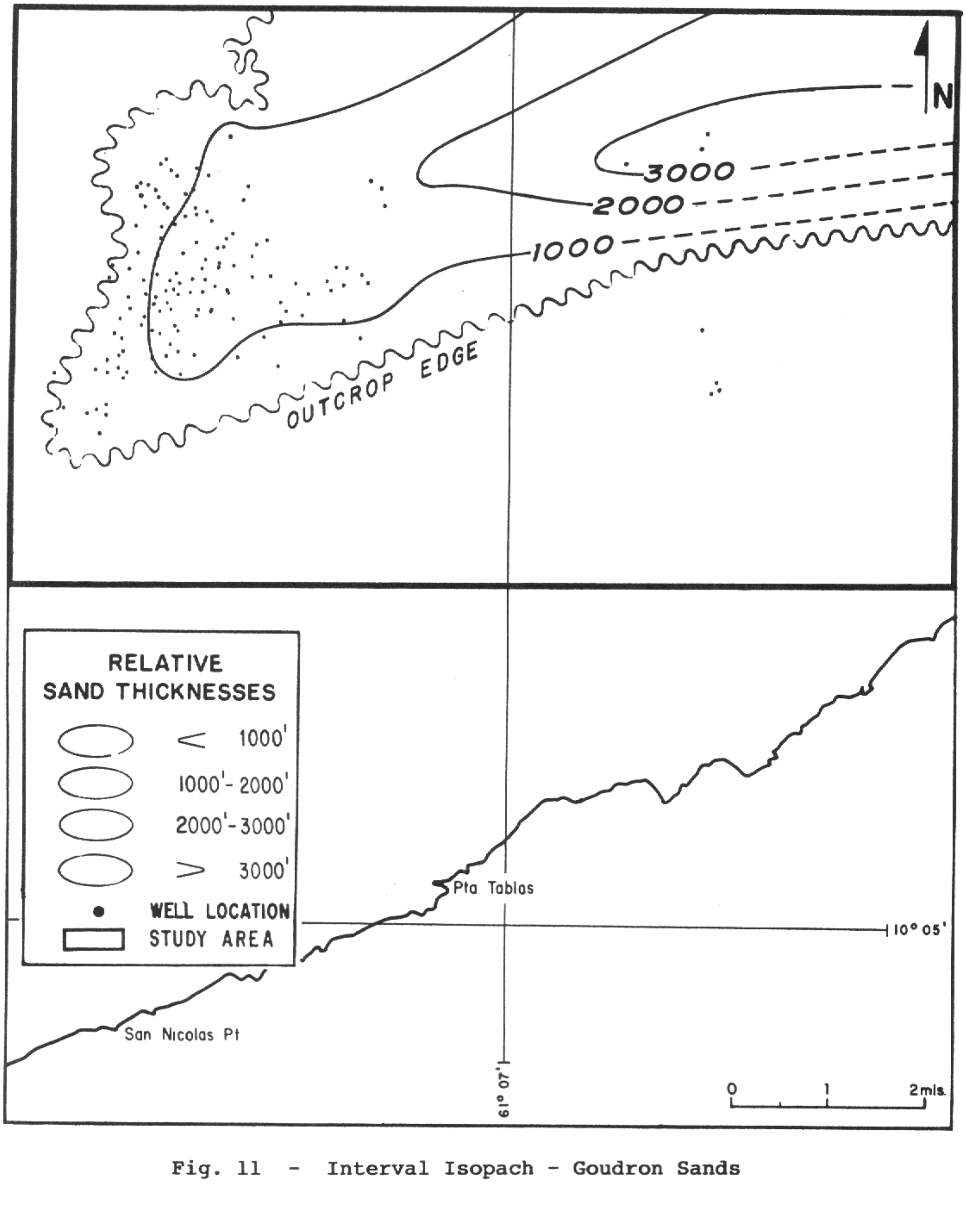

Fig. 11 - Interval Isopach - Goudron Sands

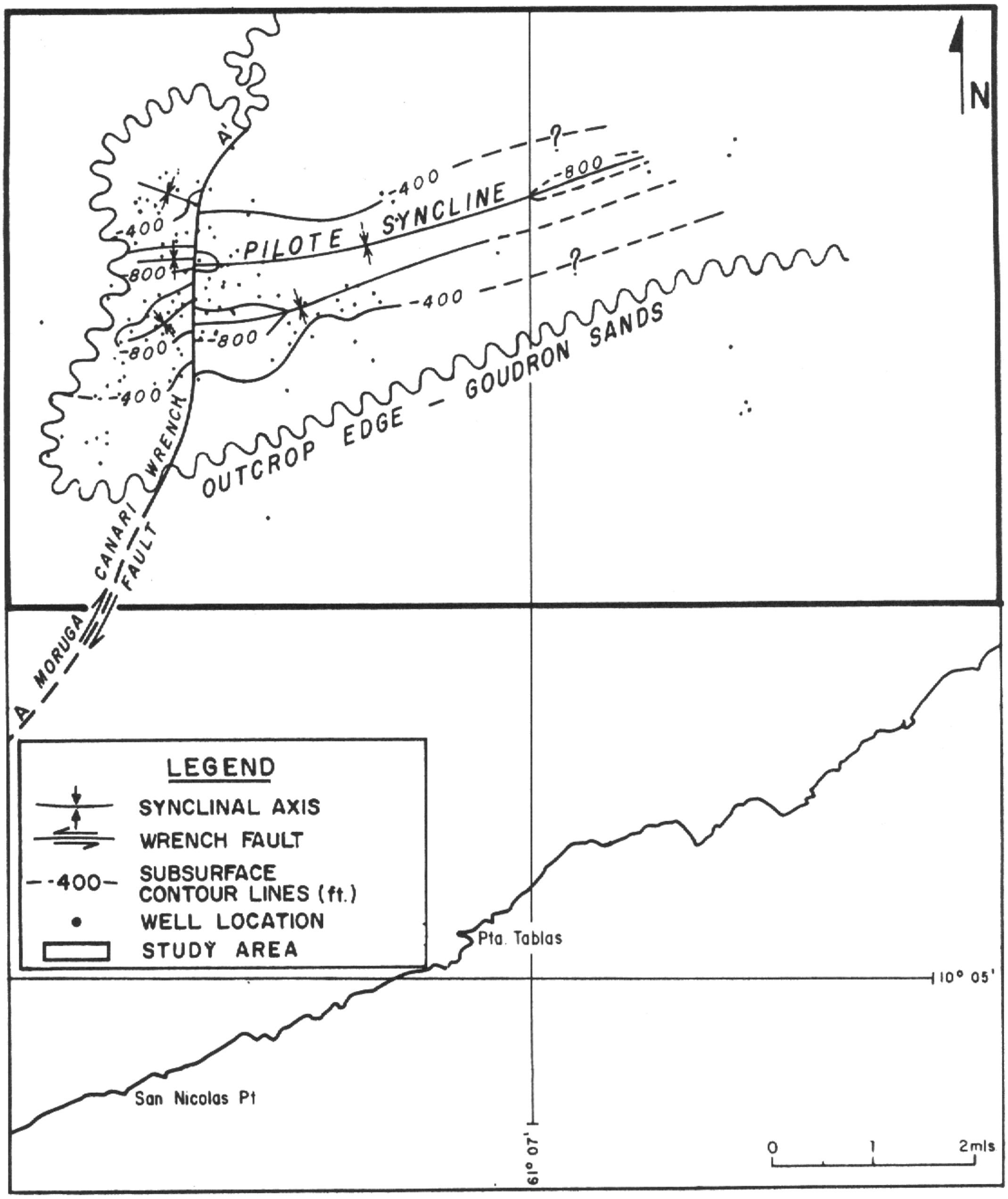

Fig. 12 - Structure Contour Map - Goudron Marker

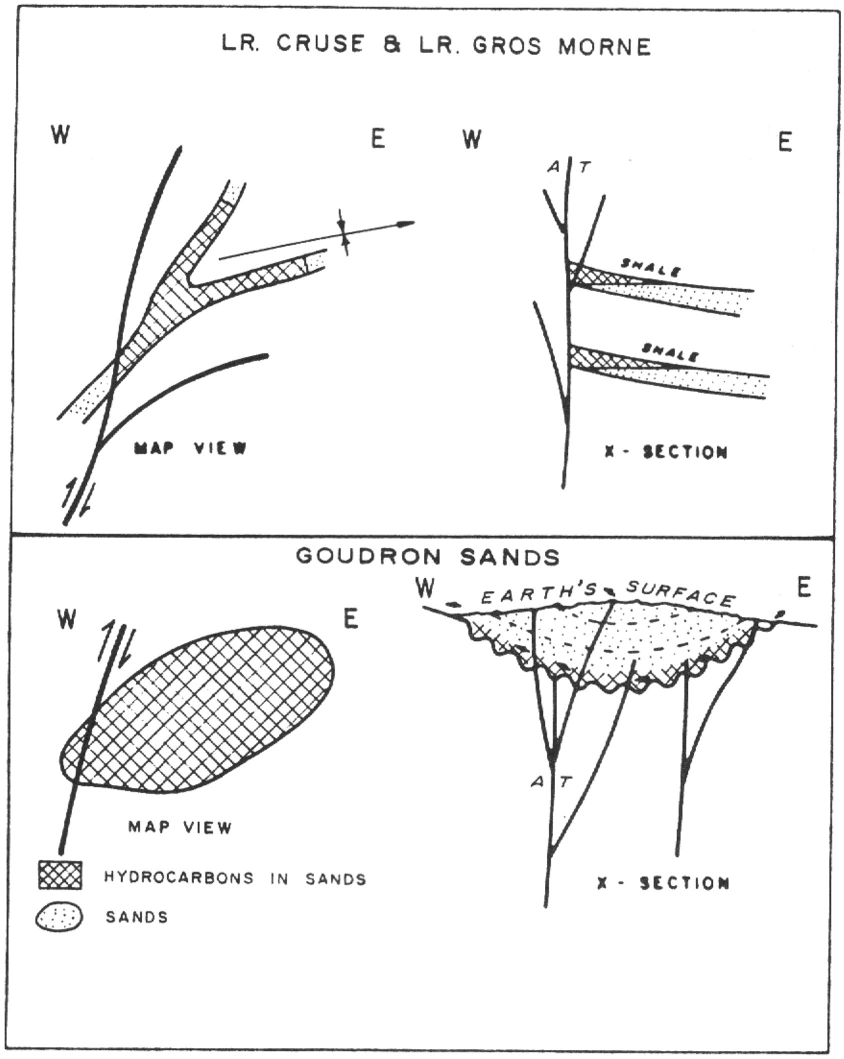

Fig. 13 - Hydrocarbon Potentials

field and beyond the field area, and that some of the faults associated with this system act as conduits for migration into reservoirs in the Moruga and Mayaro Formations.

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